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The Effect of Moving Loads on Highway Bridges

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THE EFFECT OF MOVING LOADS ON HIGHWAY BRIDGES

BY

RAY ARTHUR COLLINS

THESIS

For the Degree of

BACHELOR OF SCIENCE

IN CIVIL ENGINEERING

IN THE

COLLEGE OF ENGINEERING

OF THE

UNIVERSITY OF ILLINOIS

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RAY ARTHUR COLLINS

ENTITLED EFFECT OF MOVING LOADS ON HIGHWAY BRIDGES

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF Bachelor of Science in Civil Engineering

F. O. Guyford

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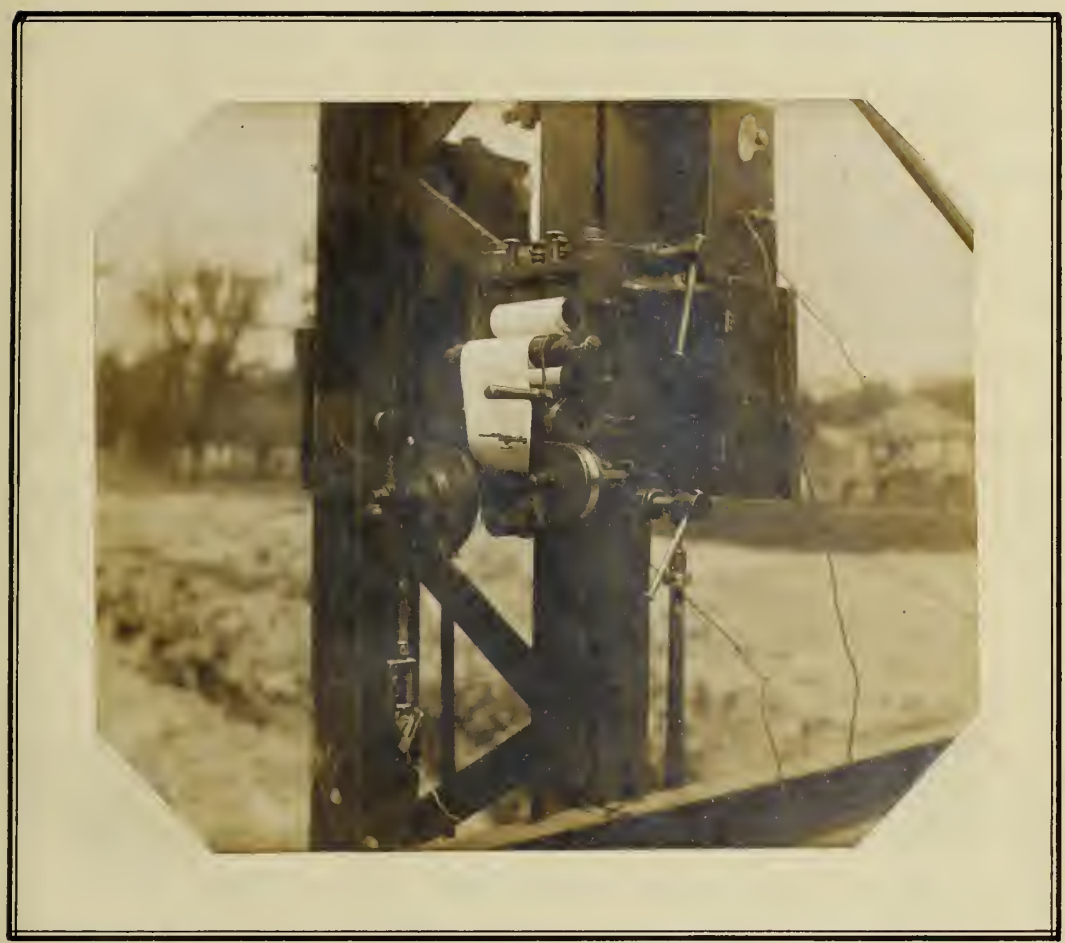
THE EFFECT OF MOVING LOADS ON HIGHWAY BRIDGES.

INTRODUCTORY

Engineers have long known that moving loads produce much greater stresses in bridge members than fixed loads of the same magnitude. The additional stress is due to impact and vibration; and to allow for this stress many empirical formulas have been devised. In the following paper a comparison is made between the actual stress caused by impact and vibration, and the stress calculated by Schneider's well-known and commonly used impact formula $I = S\left(\frac{300}{300 + L}\right)$. In which I = the impact stress, S = the live load stress, and L = the loaded length of bridge. It will readily be seen how very much in error this formula is.

The main object of the experiments, however, is to determine whether or not the different parts of the same bridge member - such as the bars of a tension member, the flanges of a compression member, or the corresponding members in the opposite trusses - act together, i. e., if they take the same impact and vibration stresses. If they do not, then the practice of building these parts identical in form should be investigated.

Plate 1.



Deflectometer in place on the Hip Vertical of the Market Street Bridge.

APPARATUS.

Two kinds of instruments were used in making these tests: one to measure the deflection of the structure as a whole, and one to measure the change in length of the individual members.

The Deflectometer, - (Plate 1, Page) This machine, modified from the original design by Professor Frankel of Dresden, Germany, is a compact steel-frame readily attachable to any flange or bar by means of clamps. The recording device consists of two electrically controlled paper drums, operated by clockwork. The pencil is attached to a steel ribbon passing over a steel wheel at each end of the paper roll. This ribbon is held taut by means of another ribbon passing over one of the steel wheels, and is held in tension on account of being connected by means of a wire to a heavy weight on the bottom of the river. Any deflection will relieve or increase the tension in this second steel ribbon and cause the pencil to move longitudinally across the roll.

The Extensometer, - (Plate 2, Page) This instrument is also operated by electrically controlled clockwork, and together with the recording rolls is enclosed in a metal box. In this instrument the pencil is operated by means of a lever arm, which, in turn, is caused to swing by the tension or compression thrown in the long rod whose far end is attached to the member at some distance from the instrument.

The calibration of these instruments has been given in Table 1. An ordinate of one inch in the extensometer diagrams corresponds to a certain stress in the bar to which the instrument has been attached. An ordinate in the deflectometer diagrams corresponds to a certain deflection of the bridge at the point where the instru-

ment was attached.

TABLE 1. CALIBRATION OF INSTRUMENTS.

Instrument	Value of One Inch of Ordinate in Lbs. per Sq. Inch	Speed of Paper in Feet per Second
Extensometer No. 1	11 300	0.642
Extensometer No. 2	11 500*	0.540*
Extensometer No. 3	12 900	0.547
Extensometer No. 7	11 500	0.613
Deflectometer	2 in.=1 in.	0.583

* Approximate.

Plate 2.

Extensometers in place on the Hip Vertical of the Market Street Bridge.

METHOD OF MAKING TESTS

The Deflectometer was generally first attached to the hip vertical, and after complete sets of readings had been taken the instrument was shifted to the intermediate post. Several arrangements of the extensometers were tried. In general the successive combinations of the instruments were:- instruments on each member in one panel; one instrument on each bar in a panel; one instrument on each flange of a compression member; and instruments on like parts in the same members in the opposite trusses. In this paper only the readings obtained from arrangements of instruments on component parts of members will be considered.

The operation of the instruments was very simple. They were all thrown into circuit with ten dry cells and a key. This key was located at one side of the road and at the end of the base line. The base line was 100 feet in length, was measured both ways from the center of the bridge, and was used to calculate the speed of the moving load by means of a signal held at one end and a stop watch at the other.

In making th-se tests two different moving loads were used: (1) a horse and double seated rig with driver (See Plate , Page) and (2) a team and loaded lumber wagon. Only the first of these was used on the Blackberry bridge on account of the distance of this bridge from any point of supply.

Various speeds were also tried: the horse and rig were sent across at a walk, trot, and gallop, and the lumber wagon at a walk and a trot. These loads at the different speeds were run across the bridge from both the free and the fixed ends.

In Table II are given the magnitudes of these loads and their

arrangement in moving load diagrams. From these diagrams the live load stresses in the bridge were calculated. The arrows represent the positions of the horse's fore and hind feet.

TABLE II. DATA FOR LOADINGS.

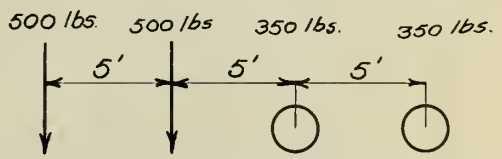
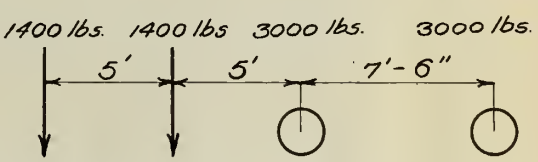
KIND	WHERE SHOWN	TOTAL WEIGHT	DIAGRAM OF TOTAL LOADS
Horse and Rig	Plate VIII Page	1700 lbs.	
Team and Lumber Wagon	Plate III Page	8800 lbs.	

Plate III

Extensometers in place on the Hip Vertical and Intermediate Post of the Market Street Bridge .

The "Heavy" Moving Load used - Team and Lumber Wagon.

DIAGRAMS FROM INSTRUMENTS

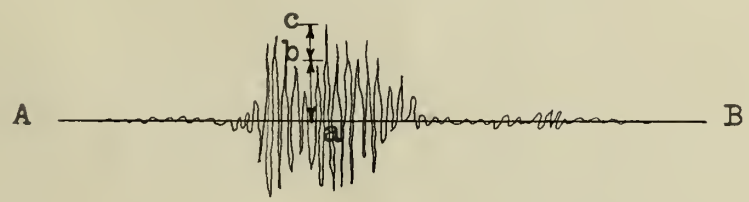
The extensometer and deflectometer diagrams furnished herewith are Van Dyke prints of tracings made from the recording rolls of the instruments. A definite system of numbering the diagrams has been followed. The first numeral is the number of the machine and the second is the number of the reading. For example:

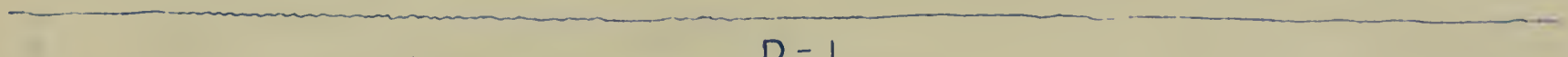
D - 4 is the fourth reading of the deflectometer.

3 - 8 is the eigth reading of extensometer No. 3.

It will be noticed that all the readings of one instrument are grouped together on succeeding pages.

The ordinates are measured from the no-load line, and are not always measured to the top of the loop in the curve, but as shown, to the top of the open loop. The closed loop represents instrumental vibration. In the accompanying diagram, AB is the no-load line, ab is the ordinate representing stress or deflection, and bc is the ordinate representing instrumental vibration.





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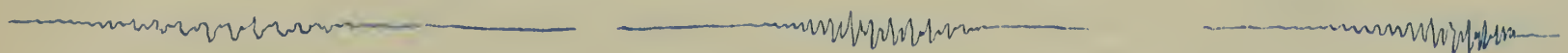
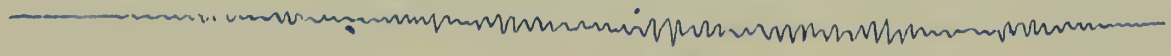


D - 4 D - 5 D - 6



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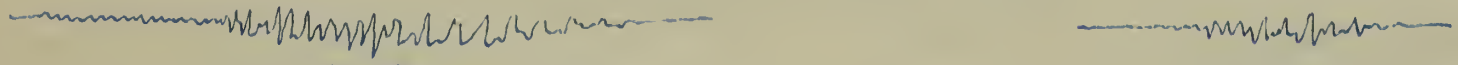

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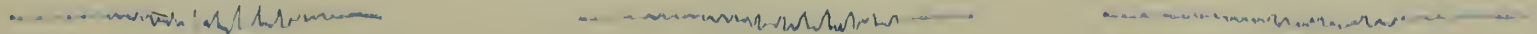

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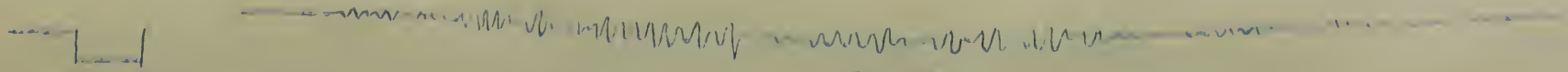

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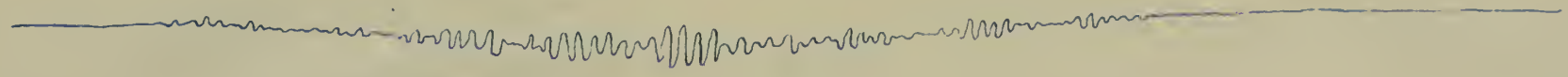

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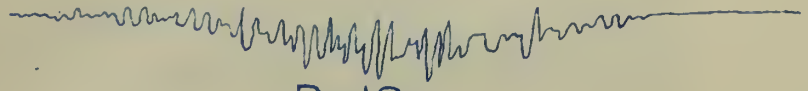

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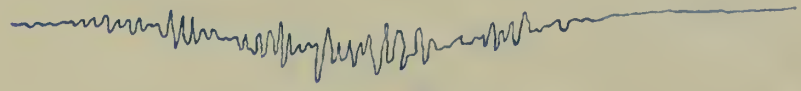

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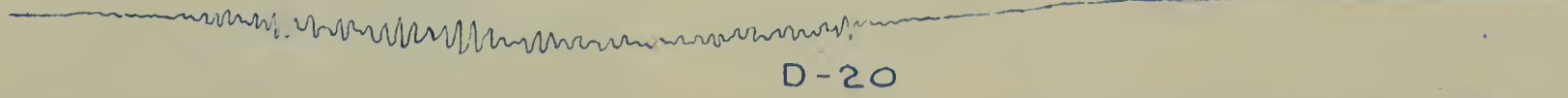

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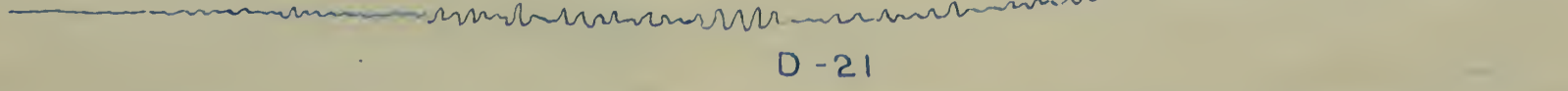

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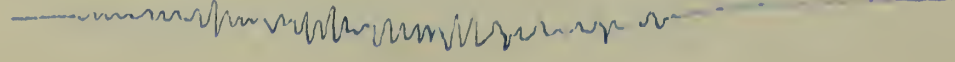

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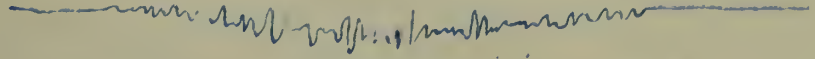

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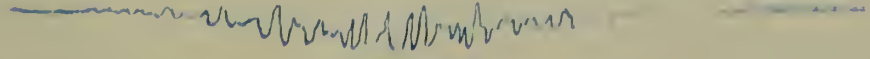

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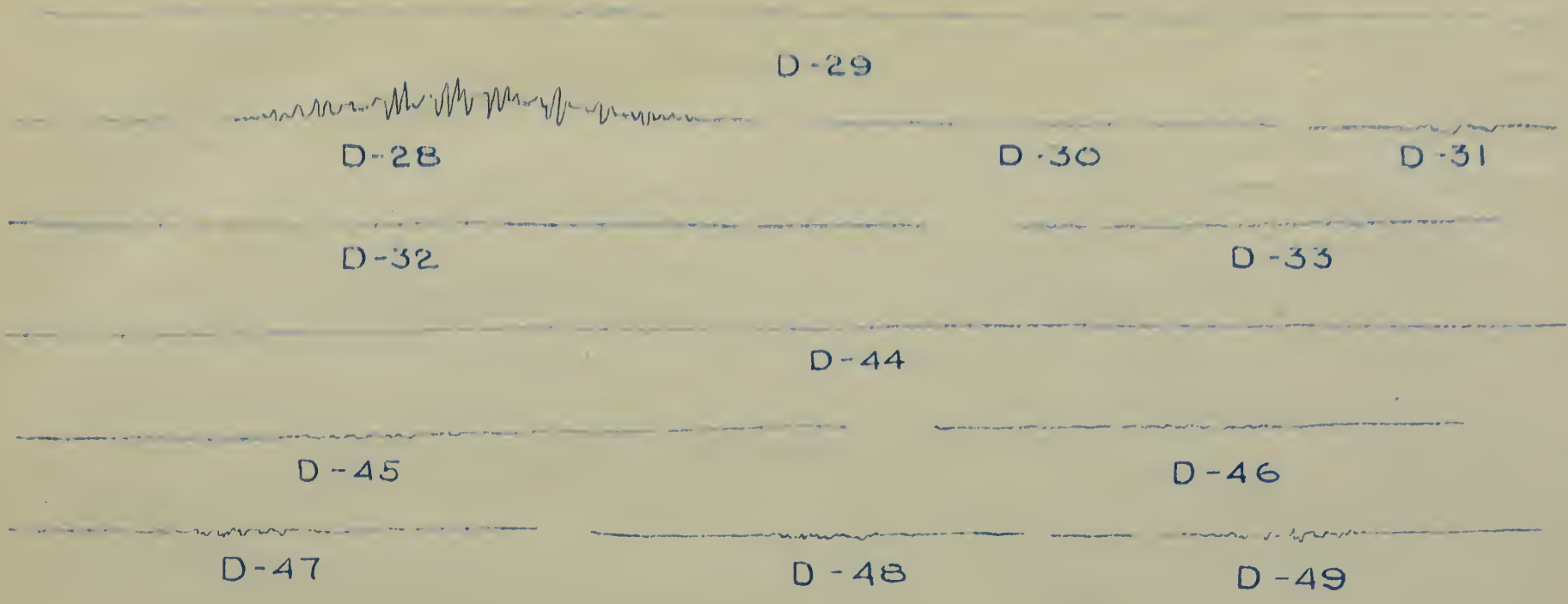
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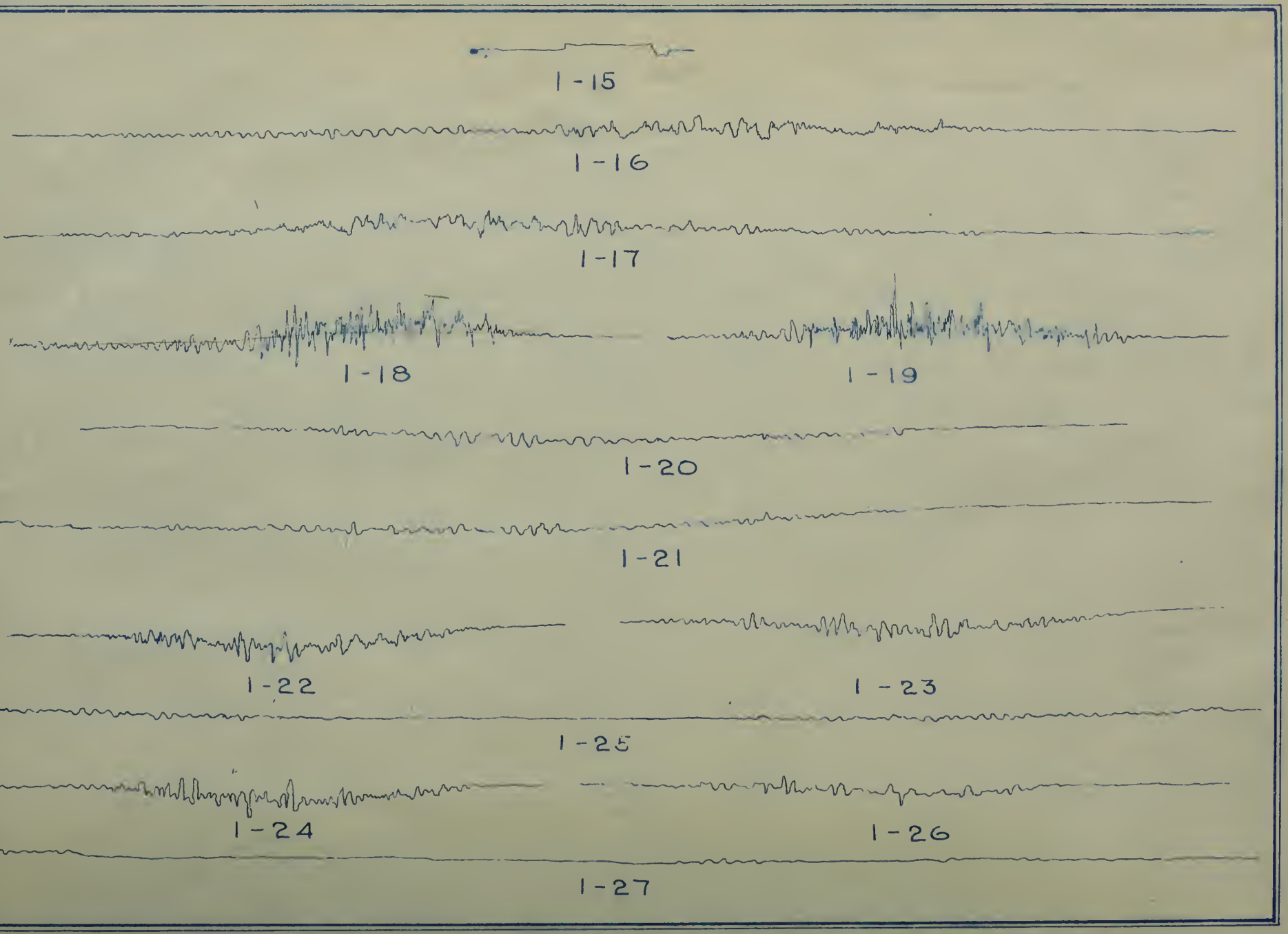
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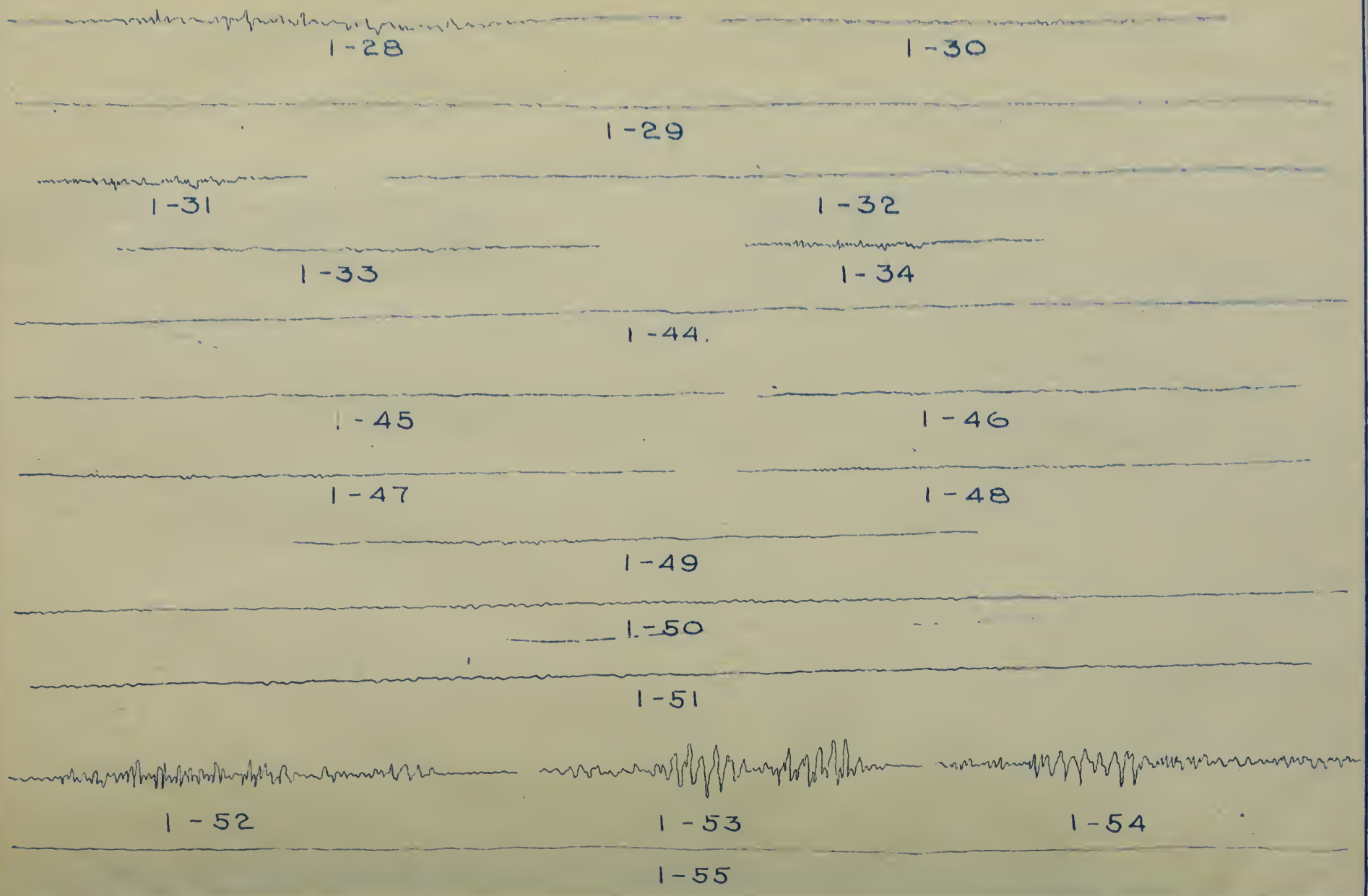
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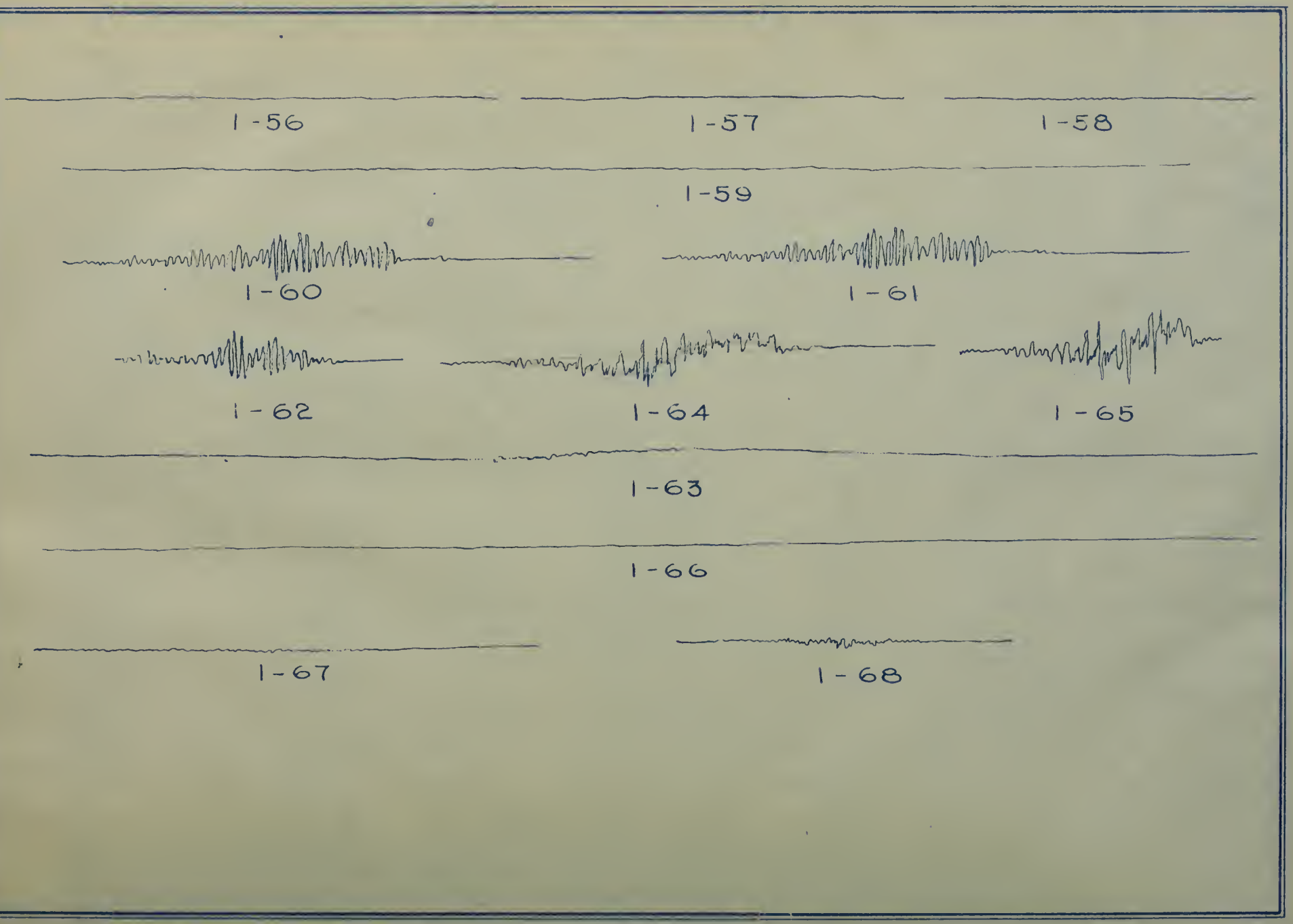
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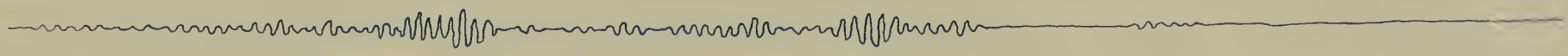

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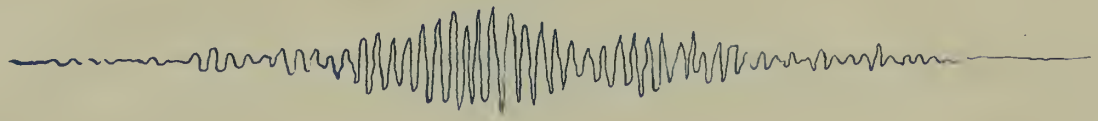

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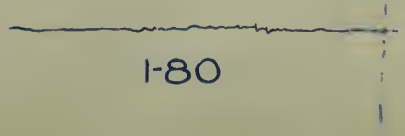

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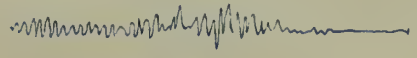

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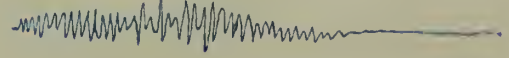

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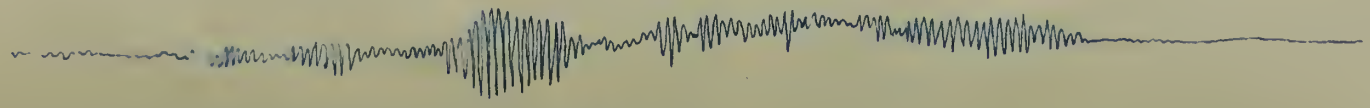

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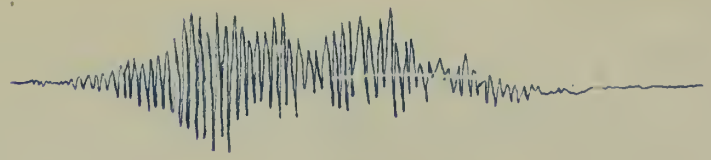

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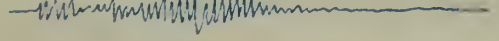

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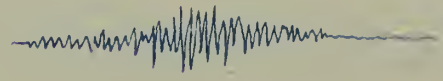

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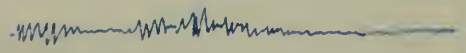

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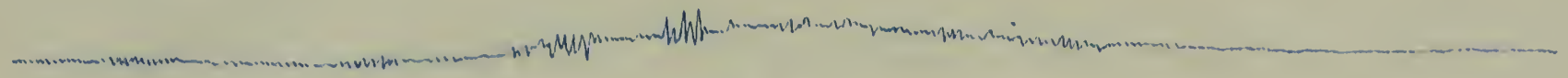

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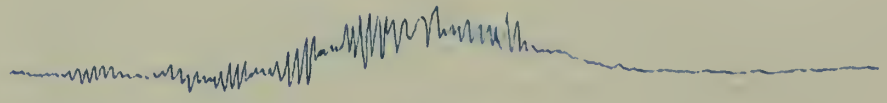

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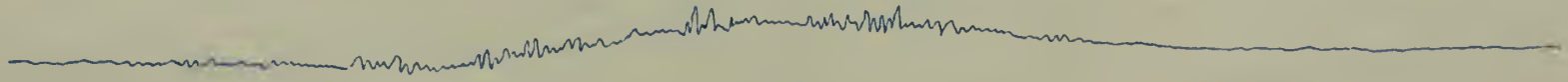

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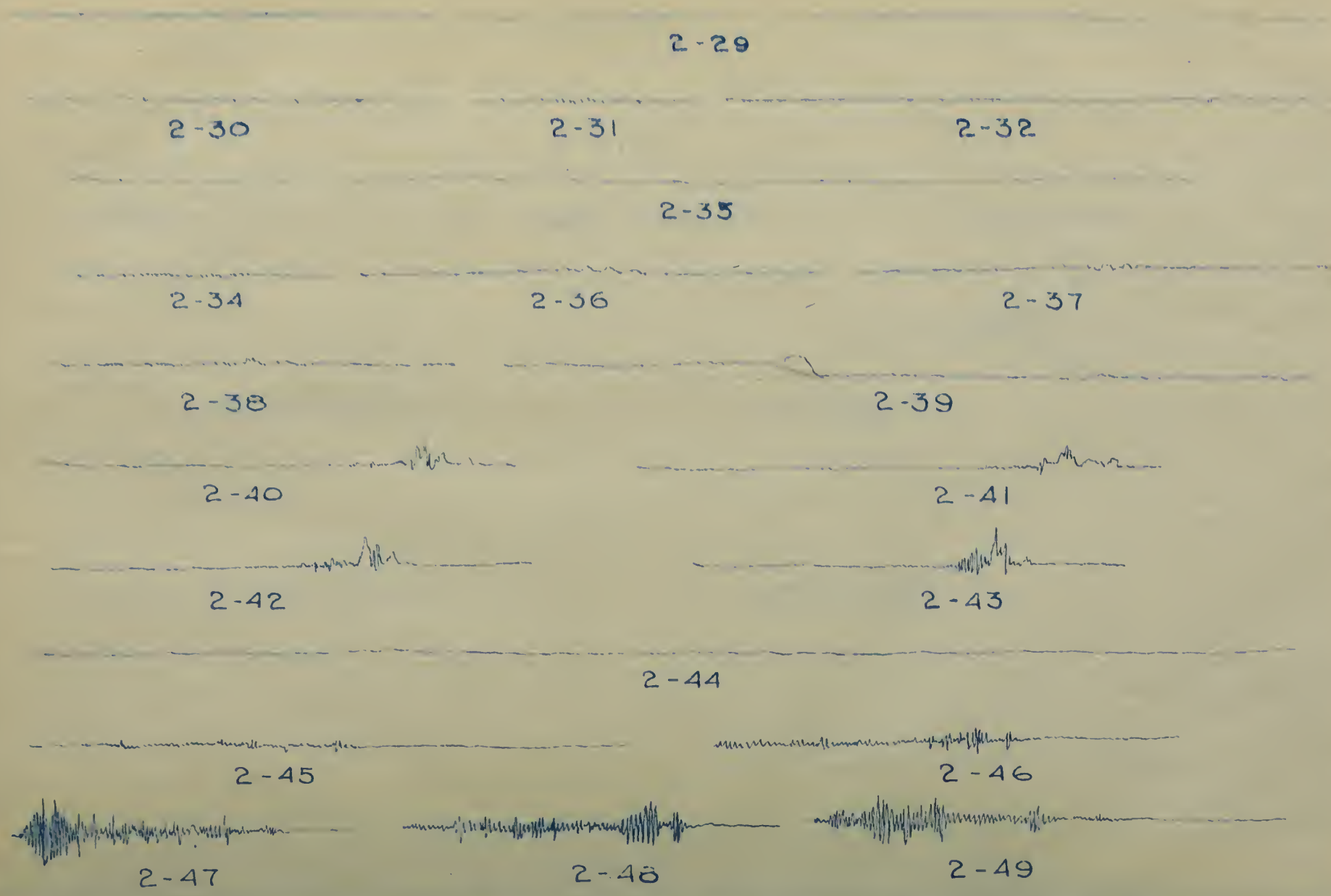
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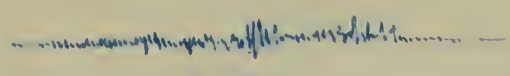

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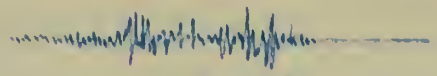

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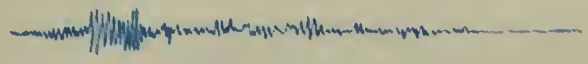

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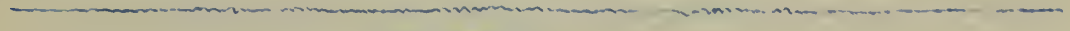

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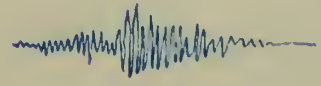

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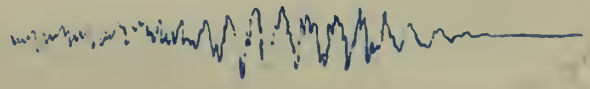

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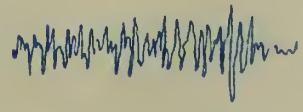

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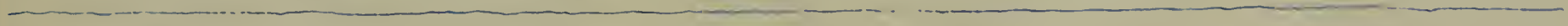

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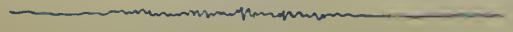

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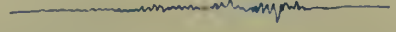

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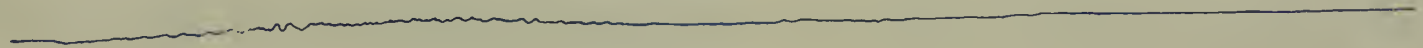

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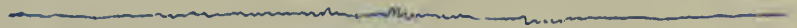

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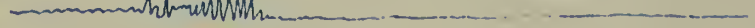

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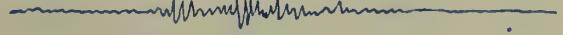

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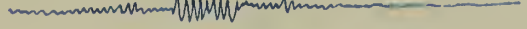

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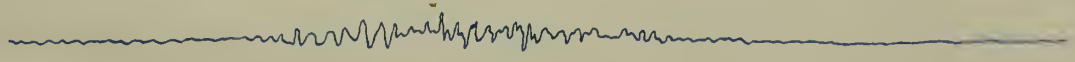

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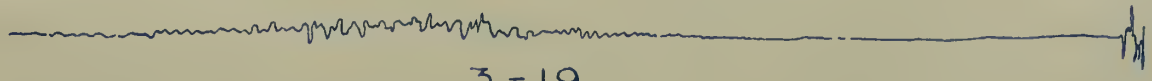

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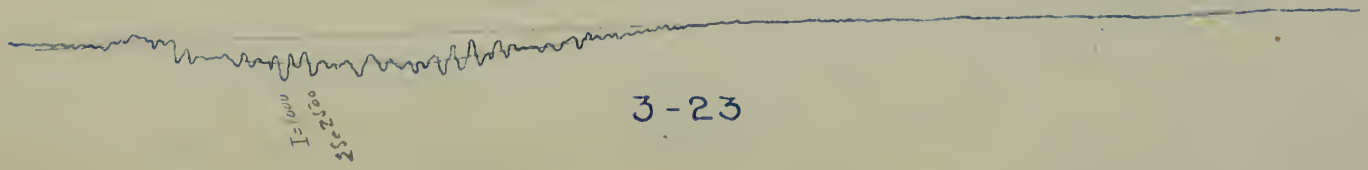

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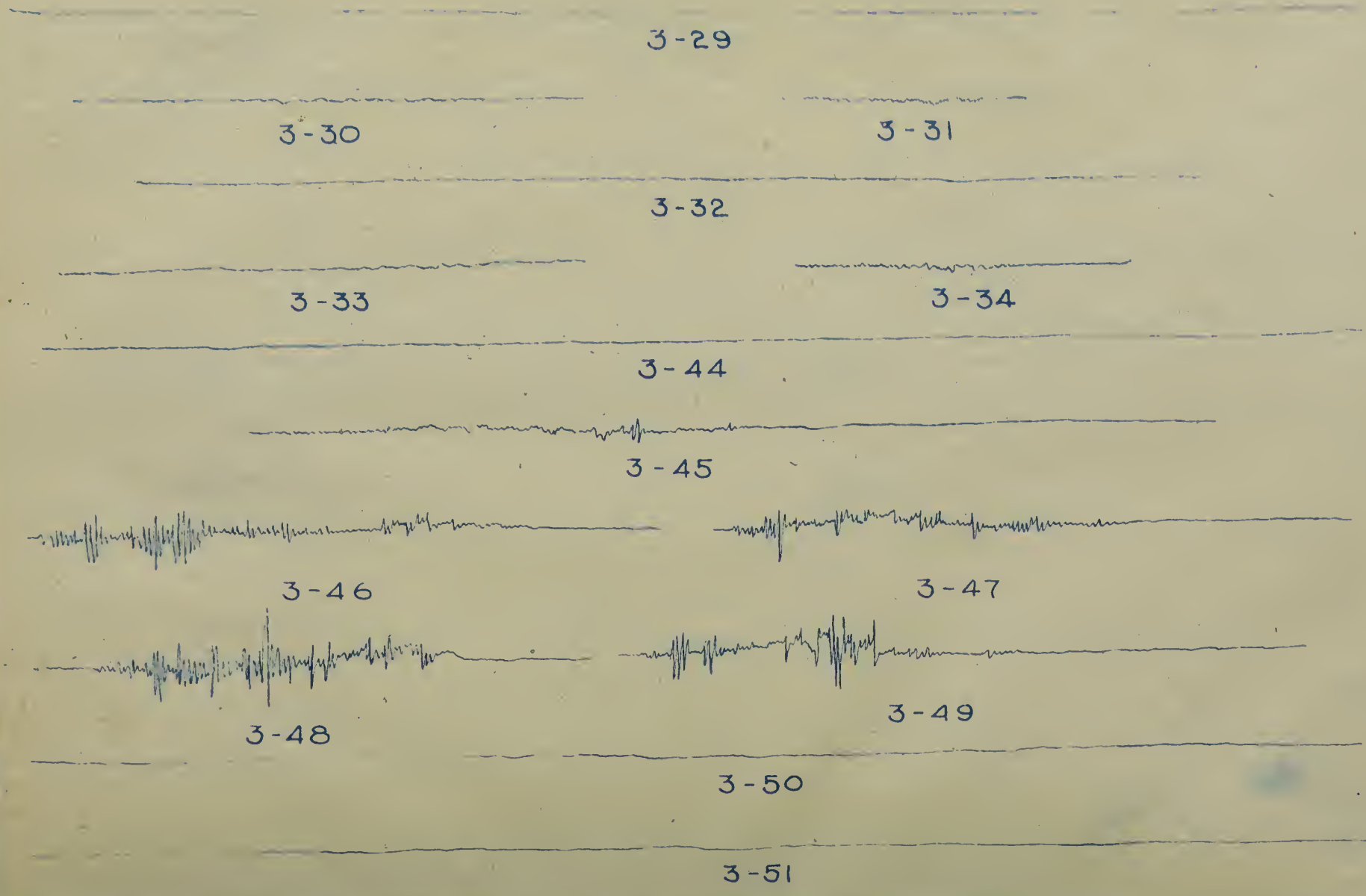
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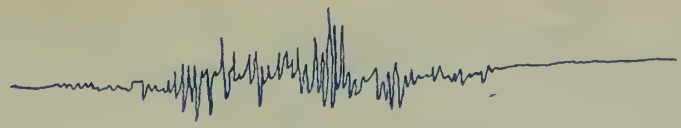

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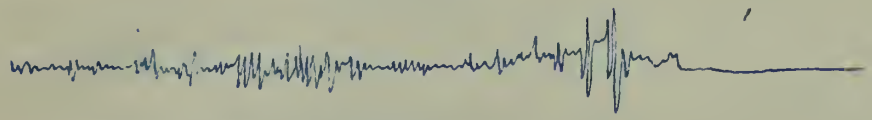

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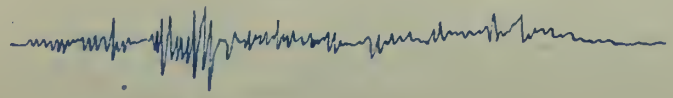

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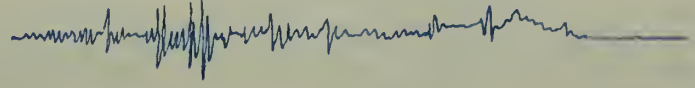

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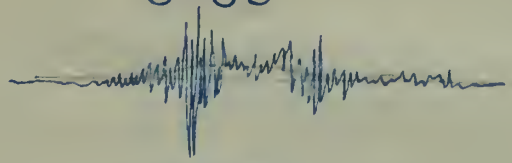

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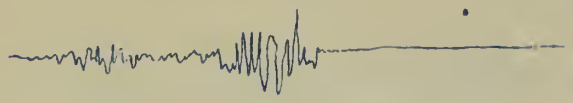

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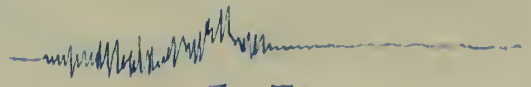

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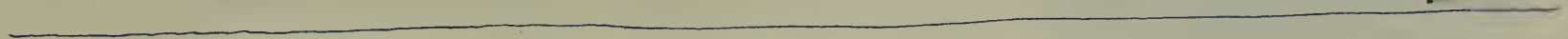

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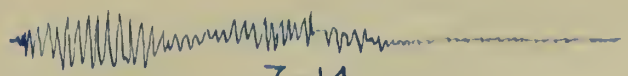

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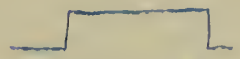

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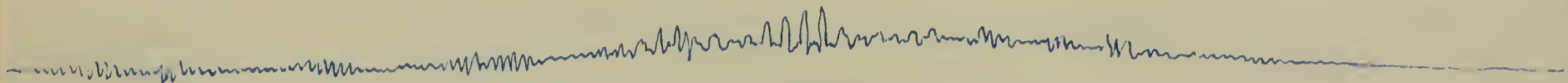

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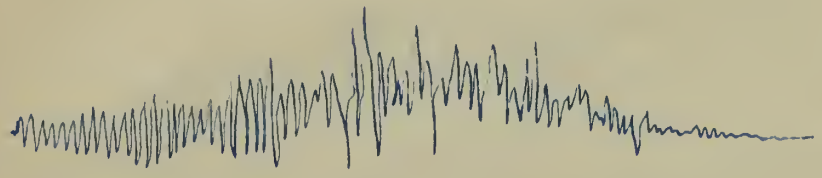

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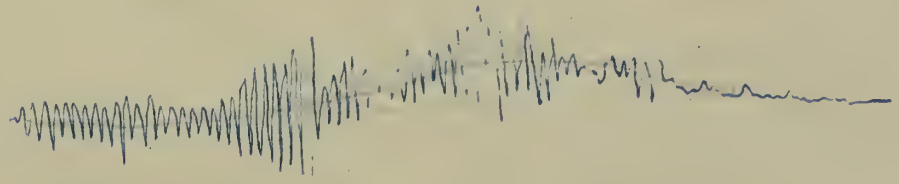

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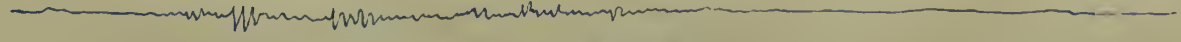

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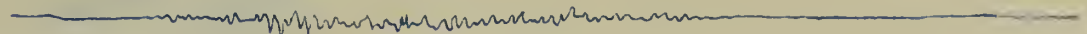

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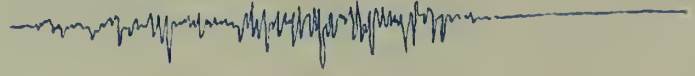

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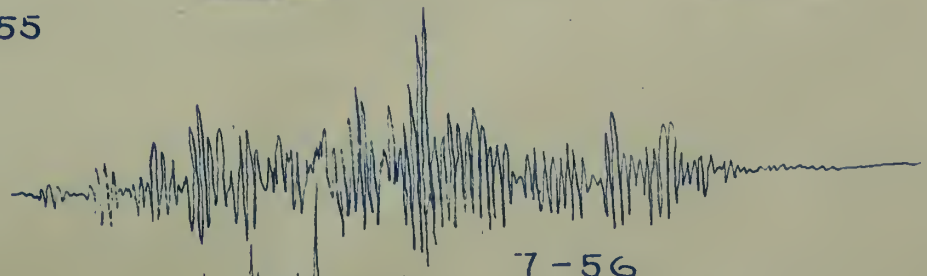

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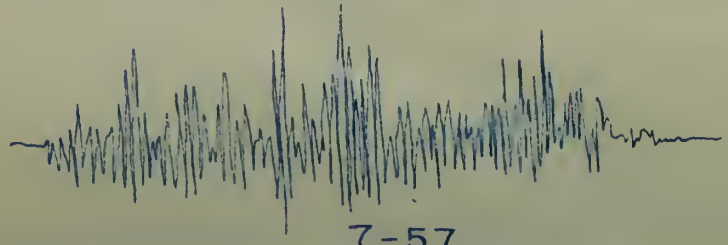

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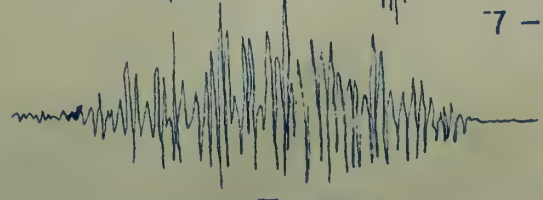

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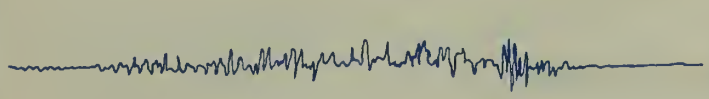

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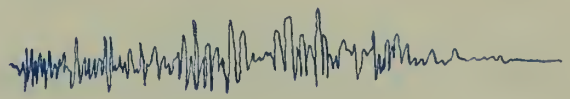

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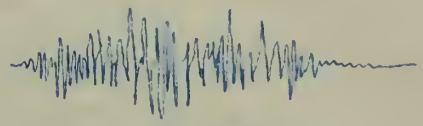

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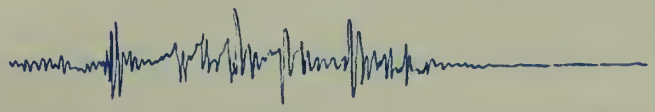

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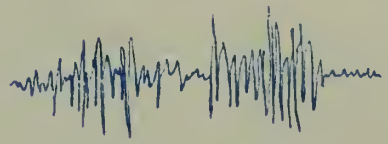

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The Market Street Bridge

The Market Street Bridge.

DESCRIPTION AND TESTS.

GENERAL DESCRIPTION OF THE MARKET STREET BRIDGE

This bridge, located on Market Street, Urbana, a thorofare running North and South across the drainage ditch, was a new structure, and here tests could be made unqualified by loose or bent members. It is shown on Plates I, II, III, IV, and V. Plate V gives the stresses and sizes of members.

The experiments were all made on the West truss since, due to the interposition of the sidewalk cantilever, it was impossible to attach instruments to the lower chord of the East truss. Corresponding tests on the two trusses would have been interesting because the East truss is more heavily built, had a sidewalk cantilever, and had a cover plated upper chord, whereas the West truss had a latticed upper chord. The structure was built by the Decatur Bridge Company.

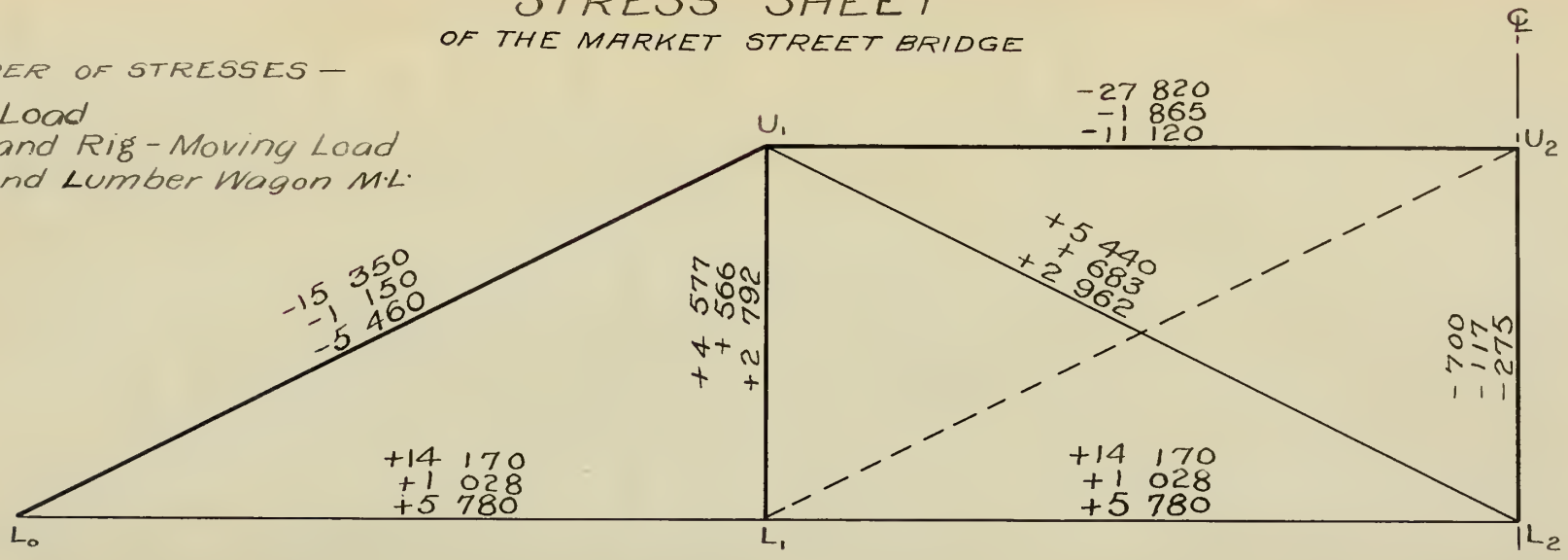
The dead load stresses on the following plate (V) were calculated from the weight of the bridge as determined by measuring in detail the sizes of the members. The live load stresses were determined by use of the moving load diagrams .

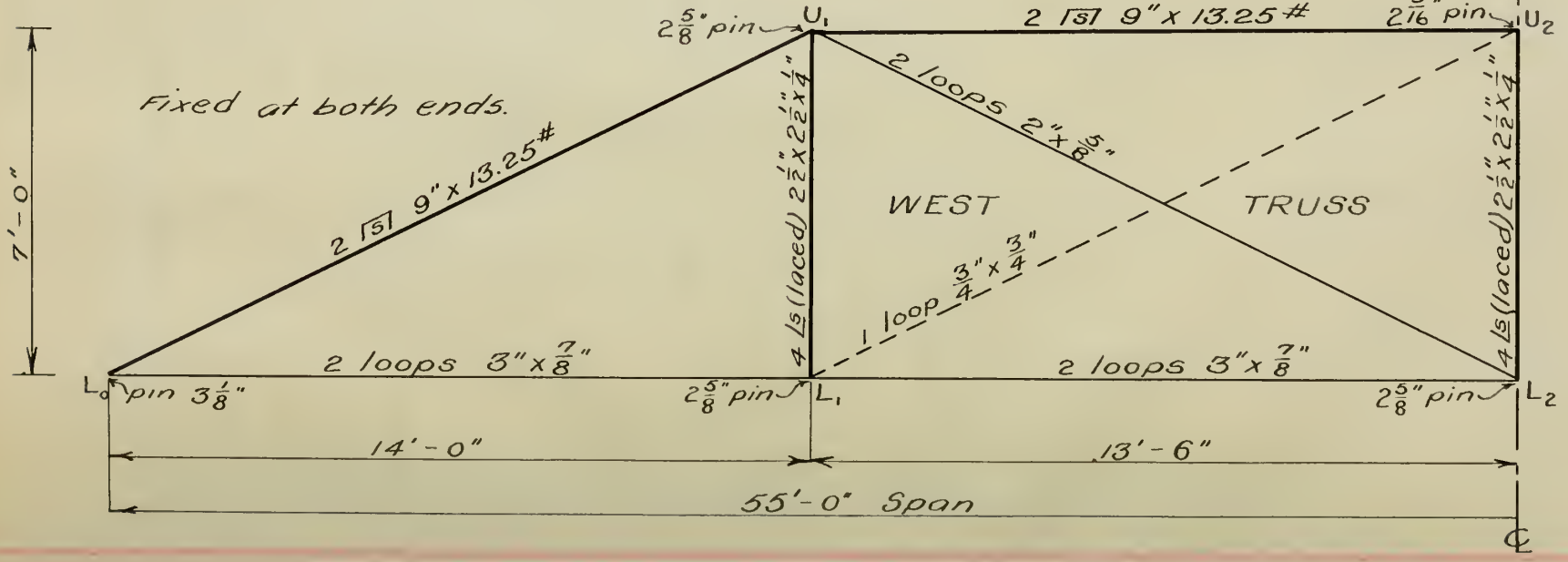
Plate V.

STRESS SHEET
OF THE MARKET STREET BRIDGE

— ORDER OF STRESSES —

Dead Load
Horse and Rig - Moving Load
Team and Lumber Wagon M.L.





EXPLANATION OF TABLES

The accompanying tables are, for the most part, self-explanatory. The column " Movement of Load to " gives the direction in which the horse was being driven when it crossed the bridge by the letters "N" (North) and "S" (South). When the Blackberry bridge is considered, account is also taken of the roller and fixed ends by the expressions "R-F" (Roller to Fixed) when the horse is traveling North, and "F-R" (Fixed to Roller) when the horse is traveling South. The column $\frac{\text{Actual}}{\text{Computed}}$ gives the ratio of these impact stresses to the base one, i. e., the figures in this column gives the number of times the actual impact stress is greater than the computed. The column "Deflection of Bridge in Inches" appears only in the first three tables, for it was subsequently found useless to make this comparison.

"Static" gait of the horse, in the column of that title, seems rather ambiguous. The readings under this head were produced by driving the horse on the bridge without starting the instruments, stopping the horse at about the center of the structure, putting the instruments in motion, obtaining a reading, stopping the instruments and driving the horse off the bridge.

The Blackberry Bridge

On the Upper Chord of Blackberry Bridge.

DESCRIPTION AND TESTS.

GENERAL DESCRIPTION OF BLACKBERRY BRIDGE

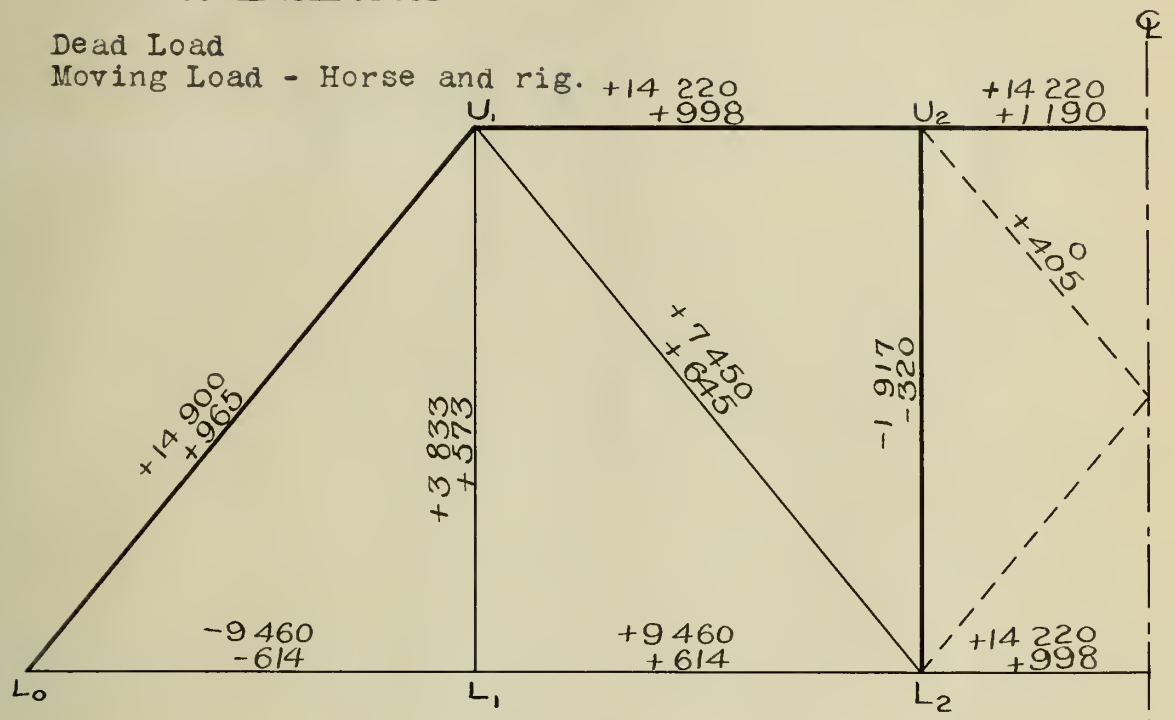
The Blackberry bridge, spanning the drainage ditch a few miles North of Urbana, Illinois, falls in the class of "light country highway bridges", and though quite old is in comparatively good condition. The bridge is illustrated in Plates VI, VII, VIII, and IX. It was noticed that the outside bar of the hip vertical at the North end of the West truss was loose, and the inside bar seemed to take all the stress. The lower chord is continuous from L_0 to L_2. The bridge does not appear to be exactly centered on the roadway since most of the traffic travels on the West side of the structure.

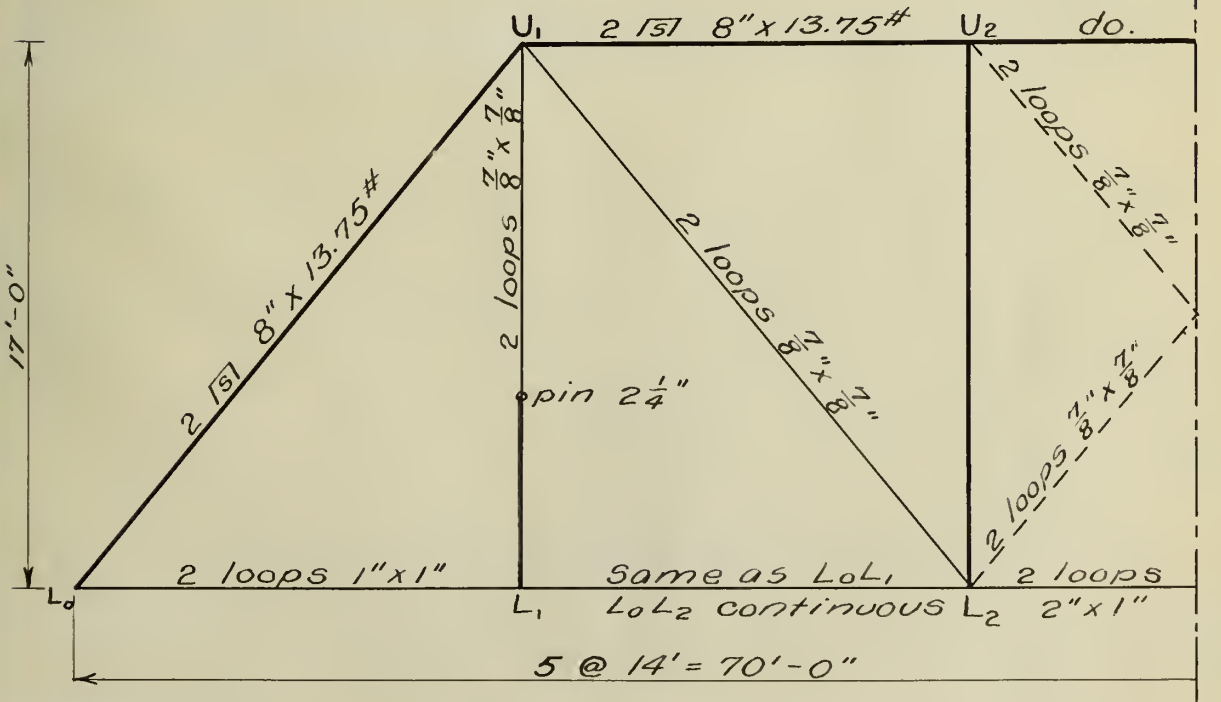
In the stress diagram on the following plate (VII), the live load stresses were calculated as before by means of the moving load diagram. The dead load used in computing the dead load stresses was found by formula.

The photograph on the preceding page (Plate VI) represents somewhat the upper lateral system, and shows the lightness of the bridge members. This bridge will shortly be taken down and re-erected to allow passage for the dredge boat.

STRESS SHEET.

Order of Stresses.





Rollers under South End of Bridge.

MARKET ST. BRIDGE — END POST — West Truss

MOVING LOAD 1700 lbs.

DETAIL	Reference Number	Movement of Load to	Computed L.L. Stress Lbs. per Sq. In.	Computed Impact Lbs. per Sq. In.	Actual ~~Impact~~ Stress Lbs. per Sq. In.	Actual / Computed	Deflection of Bridge in Inches	Gait of Horse	Speed of Horse in Mi. per Hr.
Top Inside Flange	2-26	S	148	141	1130	8	10	Trot	7.6
	2-27	N	"	"	690	5	8	Static	
	2-28	S	"	"	1035	7.5	12	Trot	6.8
	2-32	S	"	"	230	1.5	1.5	Walk	3.7
	2-33	S	"	"	345	2.5	1.5	Trot	8.1
	2-34	S	"	"	345	2.5		Gallop	17.05
Bottom Inside Flange	7-26	S	"	"	460	3.5	10	Trot	7.6
	7-28	N	"	"	690	5	12	Trot	6.8
	7-32	S	"	"	345	2.5	1.5	Walk	3.7
	7-33	S	"	"	230	1.5	1.5	Trot	8.1
	7-34	S	"	"	115	1		Gallop	17.05
Top Outside Flange	3-26	S	"	"	2324	16.5	10	Trot	7.6
	3-27	N	"	"	1550	11	8	Static	
	3-28	S	"	"	2066	15	12	Trot	6.8
	3-32	S	"	"	258	2	1.5	Walk	3.7
	3-33	S	"	"	517	3.5	1.5	Trot	8.1
	3-34	S	"	"	724	5		Gallop	17.05
Bottom Outside Flange	1-26	S	"	"	1920	13.5	10	Trot	7.6
	1-27	N	"	"	565	4	8	Static	
	1-28	S	"	"	1357	9.5	12	Trot	6.8
	1-32	S	"	"	113	1	1.5	Walk	3.7
	1-33	S	"	"	342	2.5	1.5	Trot	8.1
	1-34	S	"	"	452	3.5		Gallop	17.05

MARKET ST. BRIDGE — UPPER CHORD $U_1 U_2$ — West Truss

MOVING LOAD 1700 lbs.

DETAIL	Reference Number	Movement of Load to	Computed L.L. Stress lbs. per sq. in.	Computed Impact lbs. per sq. in.	Actual Impact Stress lbs. per sq. in.	Actual / Computed	Deflection of Bridge in Inches	Gait of Horse	Speed of Horse in mi. per hr.
Top Inside Flange	1-29	S	267	254	181	0.7	1.8	Walk	2.84
	1-30	N	"	"	452	1.8	1	Trot	6.56
	1-31	S	"	"	858	3.4	2	Gallop	14.20
Bottom Inside Flange	7-29	S	"	"	184	0.7	1.8	Walk	2.84
	7-30	N	"	"	230	0.9	1	Trot	6.56
	7-31	S	"	"	460	1.8	2	Gallop	14.20
Top Outside Flange	3-29	S	"	"	254	1.0	1.8	Walk	2.84
	3-30	N	"	"	387	1.5	1	Trot	6.56
	3-31	S	"	"	774	3.0	2	Gallop	14.20
Bottom Outside Flange	2-29	S	"	"	345	1.4	1.8	Walk	2.84
	2-30	N	"	"	230	0.9	1	Trot	6.56
	2-31	S	"	"	230	0.9	2	Gallop	14.20

MARKET ST. BRIDGE — UPPER CHORD $U_1 U_2$ — West Truss

Moving Load 8800 lbs.

DETAIL	Reference Number	Movement of Load to	Computed L.L. Stress lbs. per sq.in.	Computed Impact lbs. per sq.in.	Actual Impact Stress lbs. per sq.in.	Actual / Computed	Deflection of Bridge in Inches.	Gait of Horse	Speed of Horse mi. per hr.
Top Inside Flange	1-20	S	1430	1350	1810	1.3	13	Walk	3.28
	1-21	N	"	"	1810	1.3	13	Walk	3.41
	1-22	S	"	"	2712	2.0	13	Trot	6.82
	1-23	N	"	"	2145	15.9	12	Trot	6.56
	1-24	S	"	"	1355	10.0	12	Trot	6.88
	1-25	N	"	"	905	0.7	5	Static	
Bottom Inside Flange	7-20	S	"	"	575	.43	13	Walk	3.28
	7-21	N	"	"	460	.34	13	Walk	3.41
	7-22	S	"	"	921	.68	13	Trot	6.82
	7-23	N	"	"	1150	.85	12	Trot	6.56
	7-24	S	"	"	1150	.85	12	Trot	6.88
	7-25	N	"	"	230	.17	5	Static	
Top Outside Flange	3-23	N	"	"	2840	2.1	12	Trot	6.56
	3-24	S	"	"	2580	1.9	12	Trot	6.88
	3-25	N	"	"	904	.007	5	Static	
Bottom Outside Flange	2-23	N	"	"	1381	1.0	12	Trot	6.56
	2-24	S	"	"	2320	1.7	12	Trot	6.88
	2-25	N	"	"	806	.6	5	Static	

MARKET ST. BRIDGE — HIP VERTICAL U, L, — West Truss

	DETAIL	Reference Number	Movement of Load to	Computed Live Load Stress lbs. per sq. in.	Computed Impact Stress lbs. per sq. in.	Actual Impact Stress lbs. per sq. in.	Actual / Computed	Gait of Horse	Speed of Horse in mi. per hr.
Load 8800 lbs.	Inside Flange	7-75	N	566	535	575	1.1	Static	
		7-76	S	"	"	805	1.5	Trot	5.8
		7-77	N	"	"	345	0.6	Walk	3.1
	Outside Flange	2-75	N	"	"	1035	1.9	Static	
		2-76	S	"	"	1150	2.1	Trot	5.8
		2-77	N	"	"	920	1.7	Walk	3.1
Load 1700 lbs	Inside Flange	7-78	S	119	113	230	2.0	Walk	3.1
		7-79	N	"	"	460	4.1	Trot	6.8
		7-80	S	"	"	460	4.1	Gallop	6.2
	Outside Flange	2-78	S	"	"	230	2.0	Walk	3.1
		2-79	N	"	"	345	3.1	Trot	6.8
		2-80	S	"	"	345	3.1	Gallop	6.2

MARKET ST. BRIDGE — INTERMEDIATE POST U_2L_2 — West Truss

	DETAIL	Reference Number	Movement of Load to	Computed Live Load Stresses lbs. per sq. in.	Computed Impact Stresses lbs. per sq. in.	Actual Impact Stresses lbs. per sq. in.	Actual / Computed	Gait of Horse	Speed of Horse in mi. per hr.
8800 lbs. LOAD	Inside Flange	1-75	N	55.7	52.6	113	2.2	Static	
		1-76	S	"	"	904	17.2	Trot	5.8
		1-77	N	"	"	339	6.5	Walk	3.1
	Outside Flange	3-75	N	"	"	254	4.8	Static	
		3-76	S	"	"	516	9.8	Trot	5.8
		3-77	N	"	"	387	7.4	Walk	3.1
1700 lbs. Load	Inside Flange	1-75	N	24.6	23.4	226	9.7	Walk	3.1
		1-76	S	"	"	339	15.1	Trot	6.8
		1-77	N	"	"	452	19.3	Gallop	13.6
	Outside Flange	3-75	N	"	"	516	22.1	Walk	3.1
		3-76	S	"	"	129	5.7	Trot	6.8
		3-77	N	"	"	144	6.1	Gallop	13.6

MARKET ST. BRIDGE — MAIN DIAGONAL U_1L_2 — West Truss

MOVING LOAD 1700 lbs.

DETAIL	Reference Number	Deflection of Bridge in 1/16 Inches.	Computed Live Load Stress lbs. per sq. in.	Computed Impact Stress lbs. per sq. in.	Actual Impact Stress lbs. per sq. in.	Actual / Computed	Gait of Horse	Speed of Horse in mi. per hr.
Inside Diagonal	7-1	2	273	260	345	1.3	Walk	3.41
	7-2	3	"	"	806	3.1	Walk	3.68
	7-3	3	"	"	2 186	8.4	Trot	9.5
	7-4	5	"	"	1 840	7.1	Pace	11.4
	7-5	5	"	"	2 300	8.8	Pace	14.9
	7-6	6	"	"	3 682	13.9	Pace	13.6
	7-10	1	"	"	345	1.3	Walk	3.68
	7-11	4	"	"	2762	11.1	Pace	13.6
	7-12	3	"	"	3340	12.8	Pace	14.9
	7-13	3	"	"	3914	15.0	Pace	15.5
	7-14	3	"	"	1 610	6.2	Gallop	13.6
Outside Diagonal	2-1	2	"	"	460	1.7	Walk	3.4
	2-2	3	"	"	575	2.2	Walk	3.7
	2-3	3	"	"	1728	6.6	Trot	9.5
	2-4	5	"	"	1 610	6.2	Pace	11.4
	2-5	5	"	"	1 610	6.2	Pace	14.9
	2-6	6	"	"	1 840	7.1	Pace	13.6
	2-10	1	"	"	230	0.9	Walk	3.7
	2-11	4	"	"	1 380	5.3	Pace	13.6
	2-12	3	"	"	2070	8.0	Pace	14.9
	2-13	3	"	"	2070	8.0	Pace	15.5
	2-14	3	"	"	1 610	6.2	Gallop	13.6

MARKET ST. BRIDGE — MAIN DIAGONAL U_1L_2 — West Truss

Moving Load 8800 lbs.

DETAIL	Reference Number	Movement of Load to	Computed L.L. Stress lbs. per sq. in.	Computed Impact lbs. per sq. in.	Actual Impact Stress lbs. per sq. in.	Actual / Computed	Deflection of Bridge in Inches	Gait of Horse	Speed of Horse in mi. per hr.
Inside Diagonal	7-7	S			2760		.6	Walk	3.3
	7-8	N			2070		1.0	Trot	7.6
	7-15	N	1185	1120	2300	2.1	.9	Static	
	7-16	S	"	"			1.2	Walk	3.0
	7-17	N	"	"	4600	4.1	1.3	Walk	3.1
	7-18	S	"	"	7130	6.4	1.7	Trot	6.7
	7-19	N	"	"	6220	5.5	1.7	Trot	6.5
Outside Diagonal	2-7	S			2760		.6	Walk	3.3
	2-8	N			1380		1.0	Trot	7.6
	2-15	N	"	"	2070	1.8	.9	Static	
	2-16	S	"	"	2990	2.7	1.2	Walk	3.0
	2-17	N	"	"	3220	2.9	1.3	Walk	3.1
	2-18	S	"	"	4600	4.1	1.7	Trot	6.7
	2-19	N	"	"	4130	3.7	1.7	Trot	6.5

NOTE :- Moving load for readings 7-7 and 2-7 was a two horse team and load of coal. Weight 6060 lbs. For 7-8 and 2-8 same team and wagon Weight 5600 lbs.

MARKET ST. BRIDGE — LOWER CHORD L₀L₁ — West Truss

	DETAIL	Reference Number	Movement of Load to	Computed Live Load Stress lbs. per sq. in.	Computed Impact Stress lbs. per sq. in.	Actual Impact Stress lbs. per sq. in.	Actual / Computed	Gait of Horse	Speed of Horse in mi. per hr.
Load 1700 lbs.	Inside Bar	1-73	N	196	187	1356	7.2	Walk	3.0
		1-74	S	"	"	3164	16.9	Trot	5.5
	Outside Bar	7-73	N	"	"	186	1.0	Walk	3.0
		7-74	S	"	"	232	1.2	Trot	5.5
Load 8800 lbs	Inside Bar	2-81	S	1100	1040	454	0.5	Walk	3.5
		2-82	N	"	"	349	0.3	Trot	8.1
		2-83	S	"	"	929	0.9	Gallop	13.9
	Outside Bar	7-81	S	"	"	349	0.3	Walk	3.5
		7-82	N	"	"	580	0.6	Trot	8.1
		7-83	S	"	"	454	0.5	Gallop	13.9

Extensometers in place on the Main Diagonal, and Deflectometer in place on the Intermediate Post of Blackberry Bridge.
"Light" Moving Load used - Horse, rig, and driver.

BLACKBERRY BRIDGE — END POST L_0U_1 — West Truss

MOVING LOAD 1700 lbs.

DETAIL	Reference Number	Movement of Load to	Computed Live Load Stress lbs. per sq. in.	Computed Impact Stress lbs. per sq. in.	Actual Impact Stress lbs. per sq. in.	Actual / Computed	Gait of Horse	Speed of Horse in mi. per hr.
Inside Upper Flange	1-44	F-R	119.5	114	283	2.5	Walk	2.93
	1-45	R-F	"	"	226	2.0	Trot	7.6
	1-46	F-R	"	"	226	2.0	Trot	9.8
	1-47	R-F	"	"	396	3.5	Trot	11.3
	1-48	F-R	"	"	226	2.0	Gallop	13.6
	1-49	R-F	"	"	452	4.0	Trot	11.3
Outside Upper Flange	7-44	F-R	"	"	230	2.0	Walk	2.9
	7-45	R-F	"	"	345	3.0	Trot	7.6
	7-46	F-R	"	"	115	1.0	Trot	9.8
	7-47	R-F	"	"	230	2.0	Trot	11.3
	7-48	F-R	"	"	345	3.0	Gallop	13.6
	7-49	R-F	"	"	230	2.0	Trot	11.3

BLACKBERRY BRIDGE — UPPER CHORD U_2U_3 — West Truss

Moving Load 1860 lbs.

DETAIL	Reference Number (Plate XII)	Movement of Load	Computed Live Load Stress lbs. per sq. in.	Computed Impact Stress lbs. per sq. in.	Actual Impact Stress lbs. per sq. in.	Actual / Computed	Gait of Horse	Speed of Horse in mi. per hr.
Outside Upper Flange	7-66	R-F	147.2	140	345	2.5	Walk	3.4
	7-67	F-R	"	"	345	2.5	Trot	8.5
	7-68	R-F	"	"	230	1.6	Gallop	17.0
Inside Upper Flange	1-66	R-F	"	"	226	1.6	Walk	3.4
	1-67	F-R	"	"	452	3.2	Trot	8.5
	1-68	R-F	"	"	678	4.8	Gallop	17.0

BLACKBERRY BRIDGE

HIP VERTICAL U.L.

MOVING LOAD 1700 lbs.

DETAIL	Reference Number	Movement of Load	Computed Live Load Stress lbs. per sq.in.	Computed Impact Stress lbs. per sq.in.	Actual Impact Stress	Actual / Computed	Gait of Horse	Speed of Horse in mi. per hr.
Inside Bar West Truss	3-50	R-F	375	357	387	1.1	Walk	3.8
	3-51	F-R	"	"	387	1.1	Walk	2.9
	3-52	F-R	"	"	3 356	9.4	Trot	9.7
	3-53	R-F	"	"	2 580	7.2	Gallop	17.0
	3-54	F-R	"	"	3 356	9.4	Trot	8.5
Outside Bar West Truss	7-50	R-F	"	"			Walk	3.8
	7-51	F-R	"	"	115	0.3	Walk	2.9
	7-52	F-R	"	"	1 380	3.8	Trot	9.7
	7-53	R-F	"	"	1 840	5.2	Gallop	17.0
	7-54	F-R	"	"	2 070	5.8	Trot	8.5
Inside Bar West Truss	3-55	F-R	"	"	387	1.1	Walk	3.1
	3-56	R-F	"	"	2 322	6.3	Trot	7.6
	3-57	F-R	"	"	2 837	7.7	Trot	9.7
	3-58	R-F	"	"	3 876	7.8	Gallop	17.0
Outside Bar East Truss	7-55	F-R	"	"	690	1.9	Walk	3.1
	7-56	R-F	"	"	9 320	26.1	Trot	7.6
	7-57	F-R	"	"	8 400	22.8	Trot	9.7
	7-58	R-F	"	"	7 130	20.0	Gallop	17.0

BLACKBERRY BRIDGE — MAIN DIAGONAL U_1L_2 — West Truss

Moving Load 1700 lbs

DETAIL	Reference Number	Movement of Load	Computed Live Load Stress lbs. per sq. in.	Computed Impact Stress lbs. per sq. in.	Actual Impact Stress lbs. per sq. in.	Actual / Computed	Gait of Horse	Speed of Horse in mi. per hr.
Inside Bar	7-59	R-F	422	402	387	0.96	Walk	3.6
	7-60	F-R	"	"	452	1.1	Trot	7.6
	7-61	R-F	"	"	774	1.9	Trot	9.7
	7-62	R-F	"	"	645	1.6	Gallop	17.0
Outside Bar	3-59	R-F	"	"	345	0.9	Walk	3.6
	3-60	F-R	"	"	1 610	4.0	Trot	7.6
	3-61	R-F	"	"	3 220	8.0	Trot	9.7
	3-62	R-F	"	"	3 450	8.6	Gallop	17.0

BLACKBERRY BRIDGE

COUNTERS U_2L_3 and L_2U_3 West Truss

MOVING LOAD 1700 lbs.

DETAIL	Reference Number	Movement of Load	Computed Live Load Stress lbs. per sq. in.	Computed Impact Stress lbs. per sq. in.	Actual Impact Stress lbs. per sq. in.	Actual / Computed	Gait of Horse	Speed of Horse in mi. per hr.
U_2L_3 Inside Bar	7-63	R-F	264	252	460	1.8	Walk	3.8
	7-64	R-F	"	"	3 220	12.8	Trot	9.7
	7-65	R-F	"	"	4 140	16.5	Gallop	17.0
U_2L_3 Outside Bar	2-63	R-F	"	"	690	2.7	Walk	3.8
	2-64	R-F	"	"	2 530	10.0	Trot	9.7
	2-65	R-F	"	"	3 220	12.8	Gallop	17.0
L_2U_3 Inside Bar	3-63	R-F	"	"	254	1.0	Walk	3.8
	3-64	R-F	"	"	1 810	7.2	Trot	9.7
	3-65	R-F	"	"	2 840	11.3	Gallop	17.0
L_2U_3 Outside Bar	1-63	R-F	"	"	565	2.2	Walk	3.8
	1-64	R-F	"	"	2 710	10.1	Trot	9.7
	1-65	R-F	"	"	3 620	14.4	Gallop	17.0

BLACKBERRY BRIDGE — LOWER CHORD L_0L_2

MOVING LOAD 1700 lbs.

DETAIL	Reference Number	Movement of Load	Computed Live Load Stress lbs. per sq. in.	Computed Impact Stress lbs. per sq. in.	Actual Impact Stress lbs. per sq. in.	Actual / Computed	Gait of Horse	Speed of Horse in mi. per hr.
Inside Bar West Truss	2-50	R-F	307	292			Walk	3.8
	2-51	F-R	"	"			Walk	2.9
	2-52	F-R	"	"	1 380	4.7	Trot	9.7
	2-53	R-F	"	"	1 840	6.3	Gallop	17.0
	2-54	F-R	"	"	1 150	3.9	Trot	8.5
Outside Bar West Truss	1-50	R-F	"	"	226	0.8	Walk	3.8
	1-51	F-R	"	"	339	1.2	Walk	2.9
	1-52	F-R	"	"	1 356	4.6	Trot	9.7
	1-53	R-F	"	"	2 260	7.7	Gallop	17.0
	1-54	F-R	"	"	2 036	7.0	Trot	8.5
Inside Bar West Truss	2-55	F-R	"	"	345	1.2	Walk	3.1
	2-56	R-F	"	"	1 500	5.1	Trot	7.6
	2-57	F-R	"	"	1 380	4.7	Trot	9.7
	2-58	R-F	"	"	1 840	6.3	Gallop	17.0
Inside Bar East Truss	1-55	F-R	"	"	339	1.2	Walk	3.1
	1-56	R-F	"	"	226	0.8	Trot	7.6
	1-57	F-R	"	"	226	0.8	Trot	9.7
	1-58	R-F	"	"	226	0.8	Gallop	17.0

BLACKBERRY BRIDGE — LOWER CHORD L_2L_3 — West Truss

MOVING LOAD 1700 lbs.

DETAIL	Reference Number	Movement of Load	Computed Live Load Stress lbs. per sq. in.	Computed Impact Stress lbs. per sq. in.	Actual Impact Stress lbs. per sq. in.	Actual / Computed	Gait of Horse	Speed of Horse in mi. per hr.
Inside Bar	2-59	R-F	250	238	345	1.4	Walk	3.6
	2-60	F-R	"	"	1 840	7.7	Trot	7.6
	2-61	R-F	"	"	1 840	7.7	Trot	9.7
	2-62	R-F	"	"	2 300	9.7	Gallop	17.0
Outside Bar	1-59	R-F	"	"	226	0.9	Walk	3.6
	1-60	F-R	"	"	2486	10.4	Trot	7.6
	1-61	R-F	"	"	2486	10.4	Trot	9.7
	1-62	R-F	"	"	2486	10.4	Gallop	17.0

Extensometer in place on the Main Diagonal of the Blackberry Bridge.

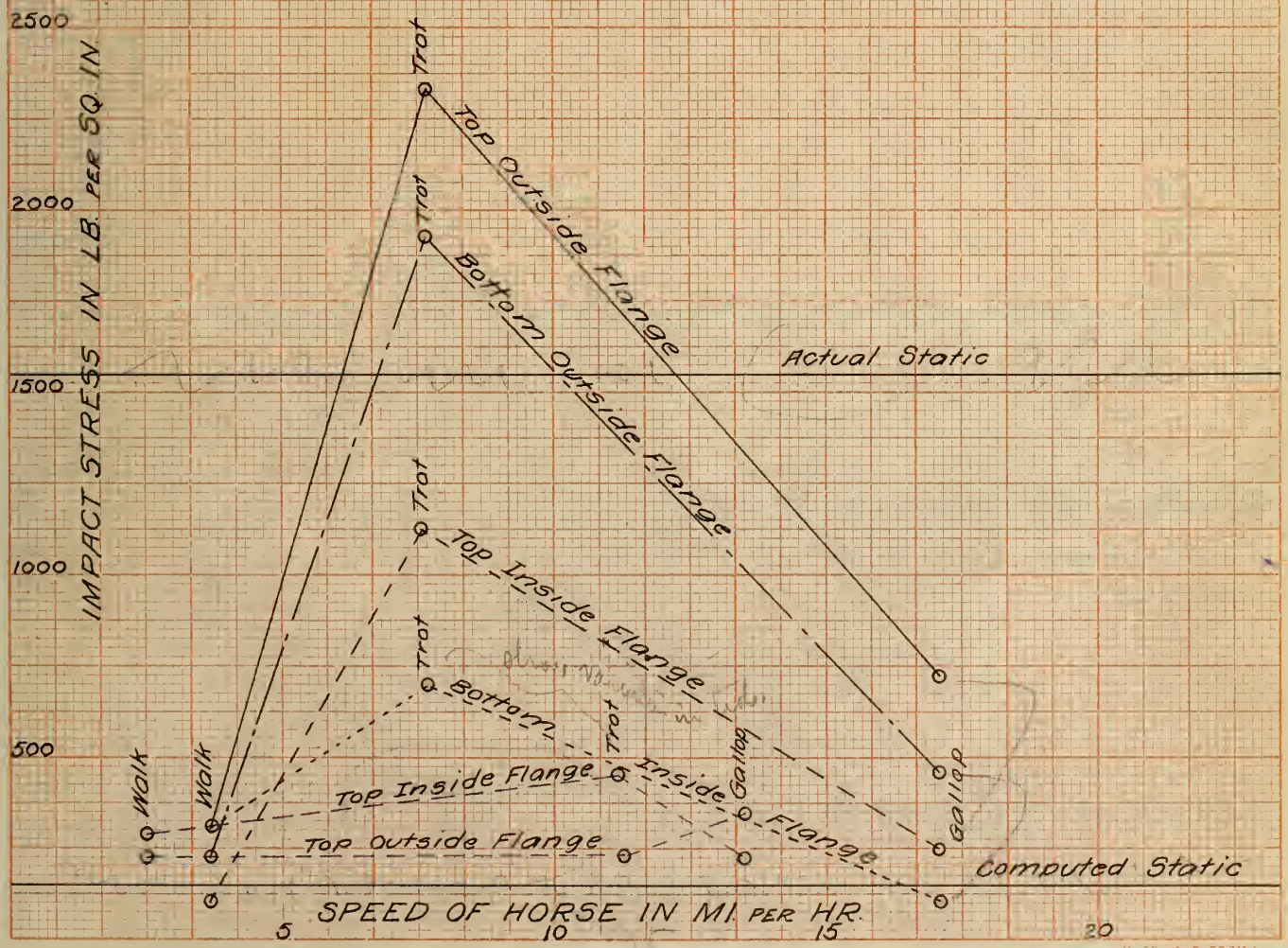
CURVES SHOWING RELATIVE IMPACT STRESSES IN THE END POST

All curves plotted from 1700-lb load readings.

Black curves represent the Market Street bridge.

Blue curves represent the Blackberry bridge.

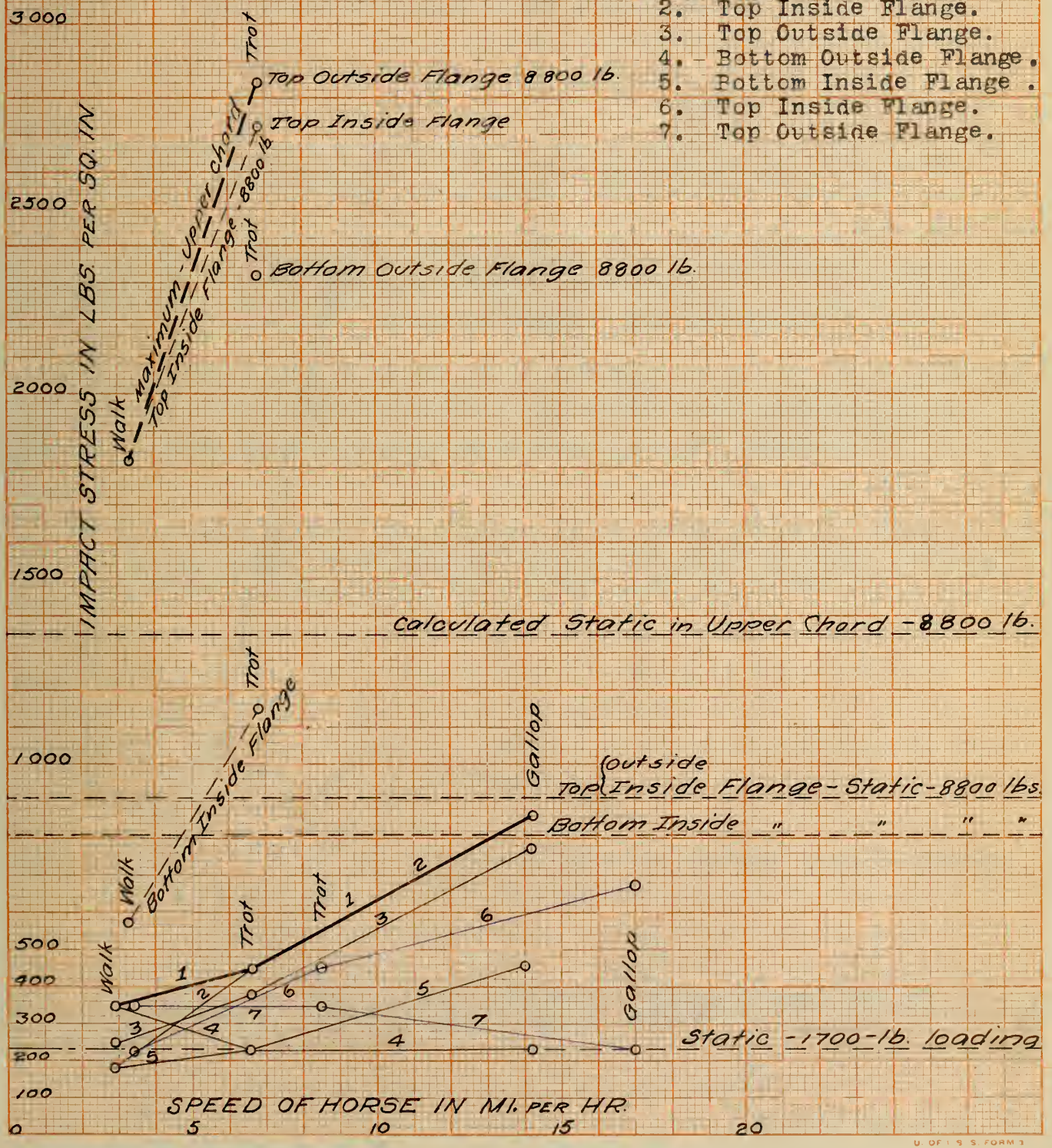
Data taken from tables III and XI.



CURVES SHOWING THE RELATIVE IMPACT STRESSES IN UPPER CHORD

Black curves represent the Market Street bridge.
Blue curves represent the Blackberry bridge.
Broken-line curves represent the 8800-lb. loading.
Solid line curves represent the 1700-lb. loading.
Heavy-line curves represent the maximum composite flange curve for the upper chord.
Data taken from Tables IV, V, and XII.

1. Upper chord (composite)
2. Top Inside Flange.
3. Top Outside Flange.
4. Bottom Outside Flange.
5. Bottom Inside Flange.
6. Top Inside Flange.
7. Top Outside Flange.

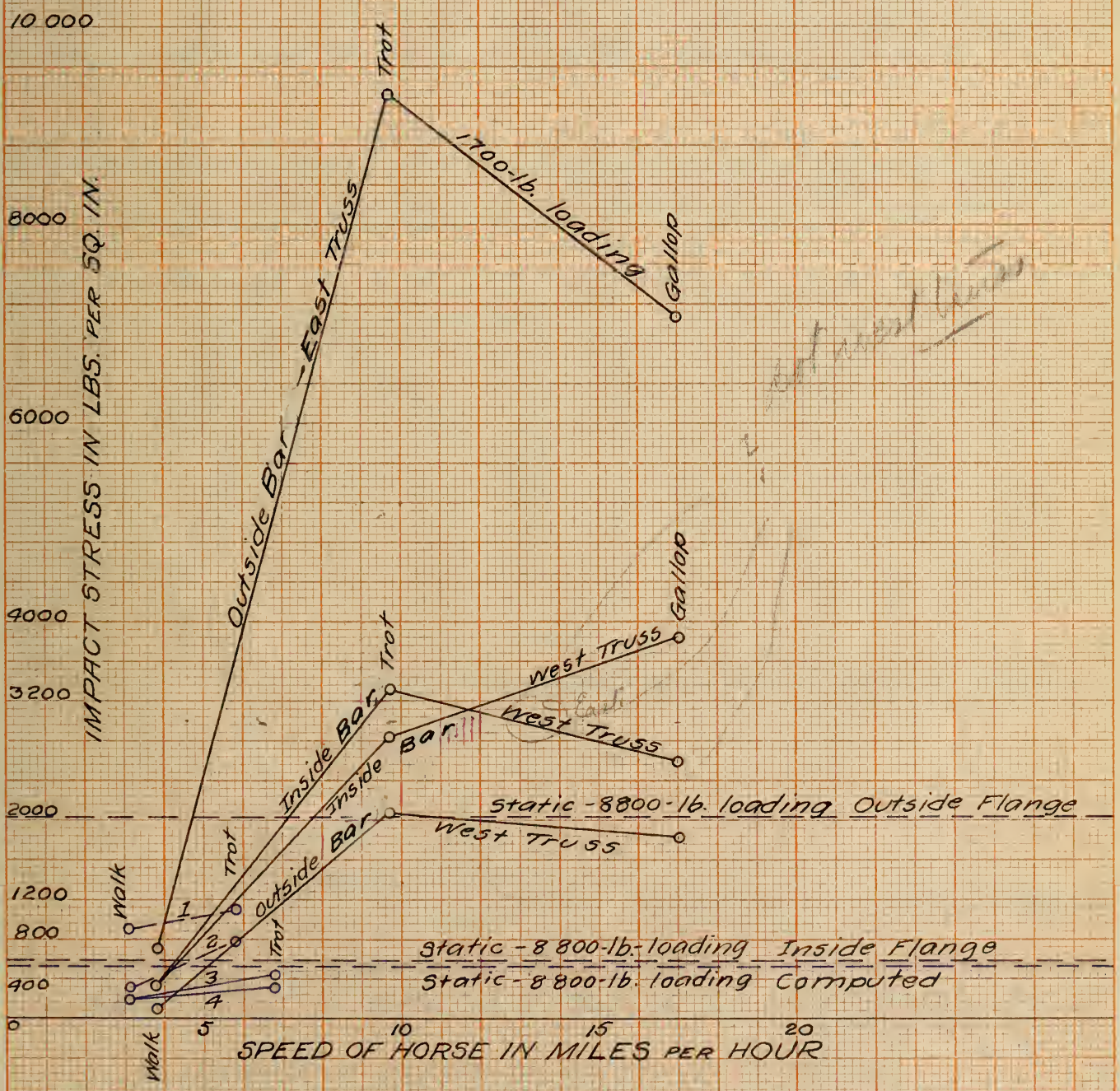


CURVES SHOWING RELATIVE IMPACT STRESSES IN THE HIP VERTICAL.

Black curves represent the Blackberry bridge.
Blue curves represent the Market Street bridge.
Solid-line curves represent the 1700-lb loading.
Broken-line curves represent the 8800-lb loading.

1. Outside flange under 8800-lb loading.
2. Inside flange under 8800-lb loading.
3. Inside flange under 1700-lb loading.
4. Outside flange under 1700-loading.

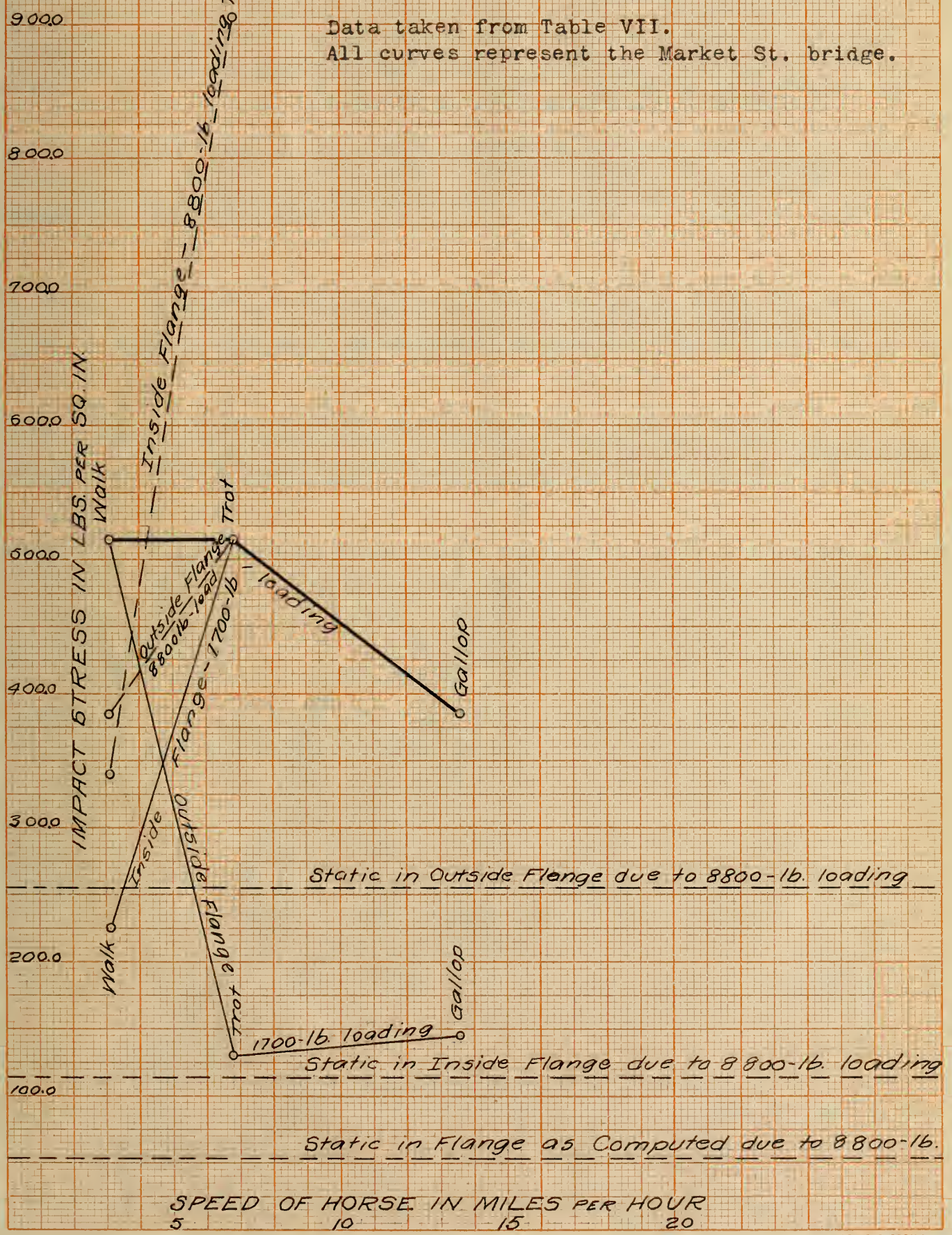
Data taken from Tables VI, and XIII.



U OF I. S. S. FORM 3

CURVES SHOWING RELATIVE STRESSES IN THE INTERMEDIATE POST.

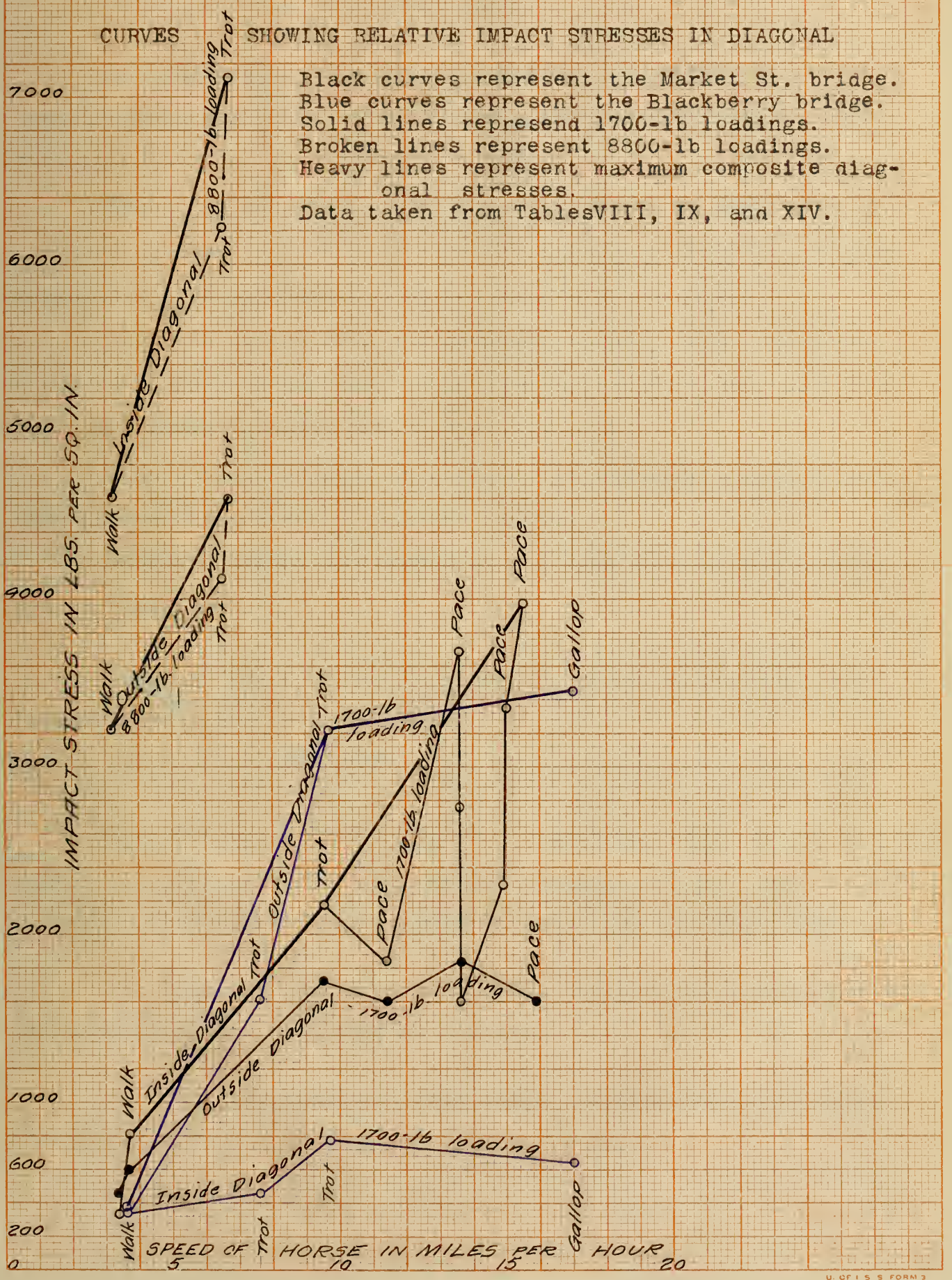
Data taken from Table VII.
All curves represent the Market St. bridge.



U. OF S. S. FORM 3

CURVES SHOWING RELATIVE IMPACT STRESSES IN DIAGONAL

Black curves represent the Market St. bridge.
Blue curves represent the Blackberry bridge.
Solid lines represend 1700-lb loadings.
Broken lines represent 8800-lb loadings.
Heavy lines represent maximum composite diagonal stresses.
Data taken from TablesVIII, IX, and XIV.



V CONCLUSIONS

1. The greater the load the greater the stress, but that the stress in most cases increases faster than the load, in some instances three or four times as rapidly.

Except in one case, that of the upper chord, the static stresses as computed are less than the actual as shown by the diagrams, but this difference does not vary with the load.

That the stress does not increase directly with the speed, but more rapidly, especially in the tension members; and that this increase becomes greater the heavier the load.

That the differences in stresses in component parts of the same member vary directly with the loading.

That the effect of loading is the same in both compression and tension members.

2. That the stresses increase in triple or quadruple the ratio of the speed in most cases.

That a trot produces greater stresses than any other gait.

3. That the component parts of the same member do not act together. The outer bars of tension members, and the outer flanges of compression members take greater stress than the inner ones.

4. That the action of the impact stresses is independent of the deflection of the bridge as a whole.

5. That the direction from which the live-load approaches the bridge has no effect on the impact stresses.

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